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Naim et al.

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(54) **SYSTEMS AND METHODS OF MANAGING FREQUENCY BAND SELECTION**

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(51) **Int. Cl.**

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H04W 72/08	(2009.01)
H04W 36/30	(2009.01)
H04W 36/06	(2009.01)

(52) **U.S. Cl.**
CPC ***H04W 72/085*** (2013.01); ***H04W 36/30*** (2013.01); *H04W 36/06* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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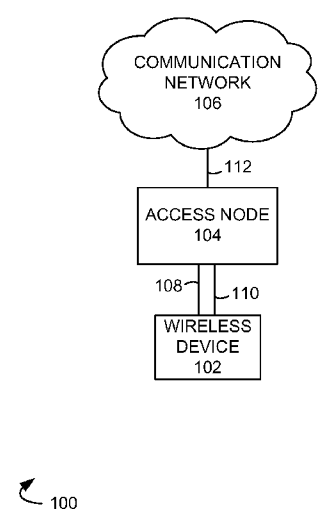
(57) **ABSTRACT**

In systems and methods of managing frequency band selection for a wireless device, a first signal level of a first frequency band and a second signal level of a second frequency band received at a wireless device are monitored, wherein the first frequency band comprises a lower frequency band than the second frequency band. A first signal level difference is determined between the first signal level and the second signal level, and the wireless device is instructed to communicate with the access node over the second frequency band when the first signal level difference meets a first signal level difference criteria based on a decrease of the second signal level.

14 Claims, 9 Drawing Sheets



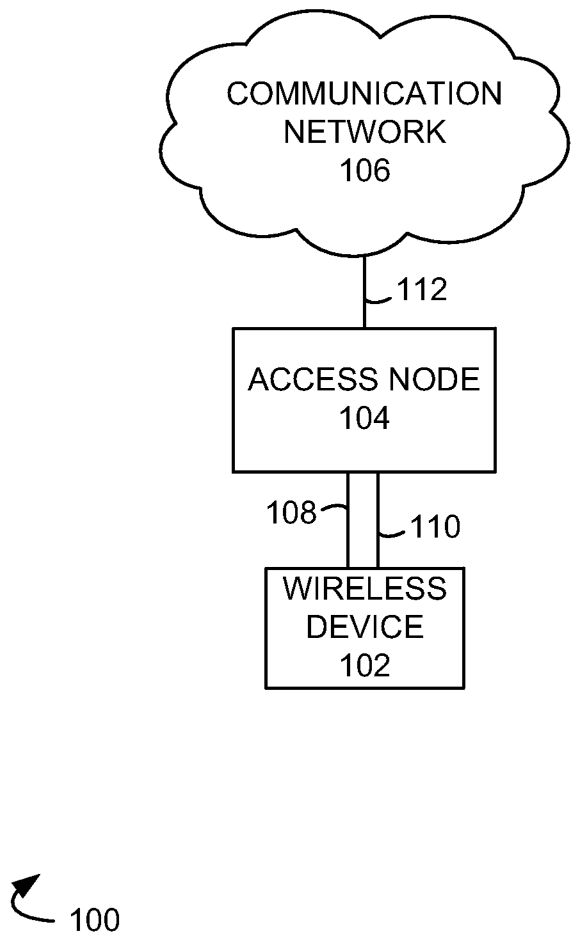

COMMUNICATION
NETWORK
106
112
ACCESS NODE
104
108
110
WIRELESS
DEVICE
102
100

FIG. 1

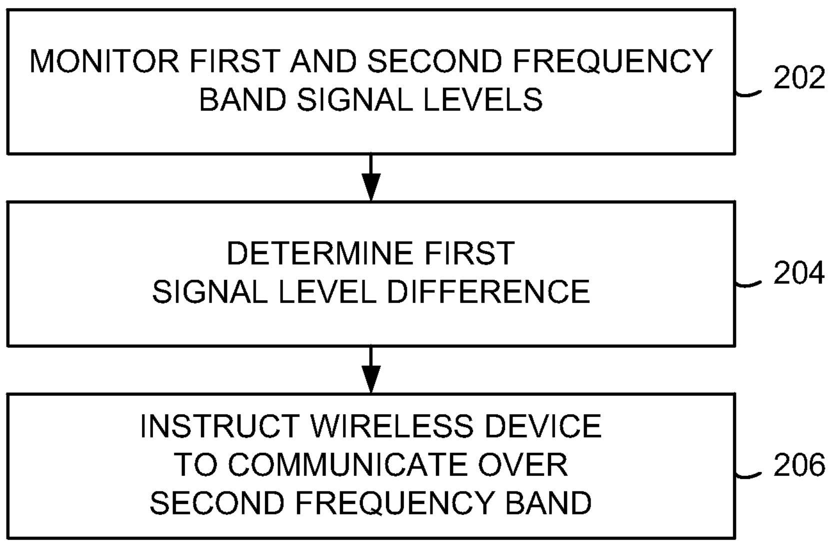

MONITOR FIRST AND SECOND FREQUENCY BAND SIGNAL LEVELS
202
DETERMINE FIRST SIGNAL LEVEL DIFFERENCE
204
INSTRUCT WIRELESS DEVICE TO COMMUNICATE OVER SECOND FREQUENCY BAND
206

FIG. 2

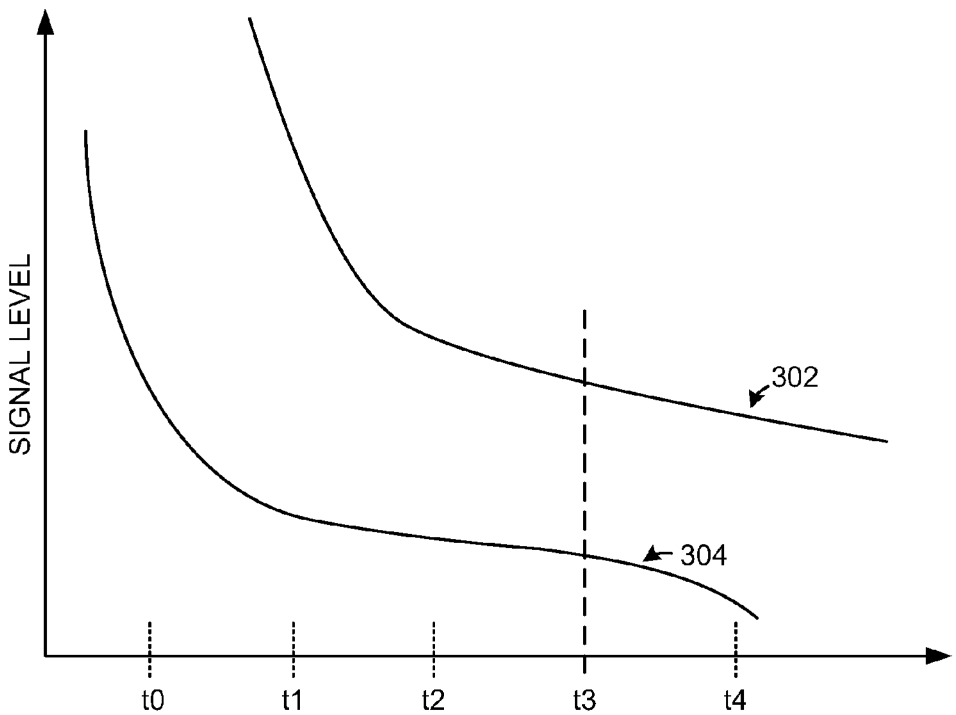


FIG. 3A

	t0	t1	t2	t3	t4
SL 302	-10%	-10%	-10%	-11%	-12%
SL 304	-11%	-11%	-11%	-15%	-20%

FIG. 3B

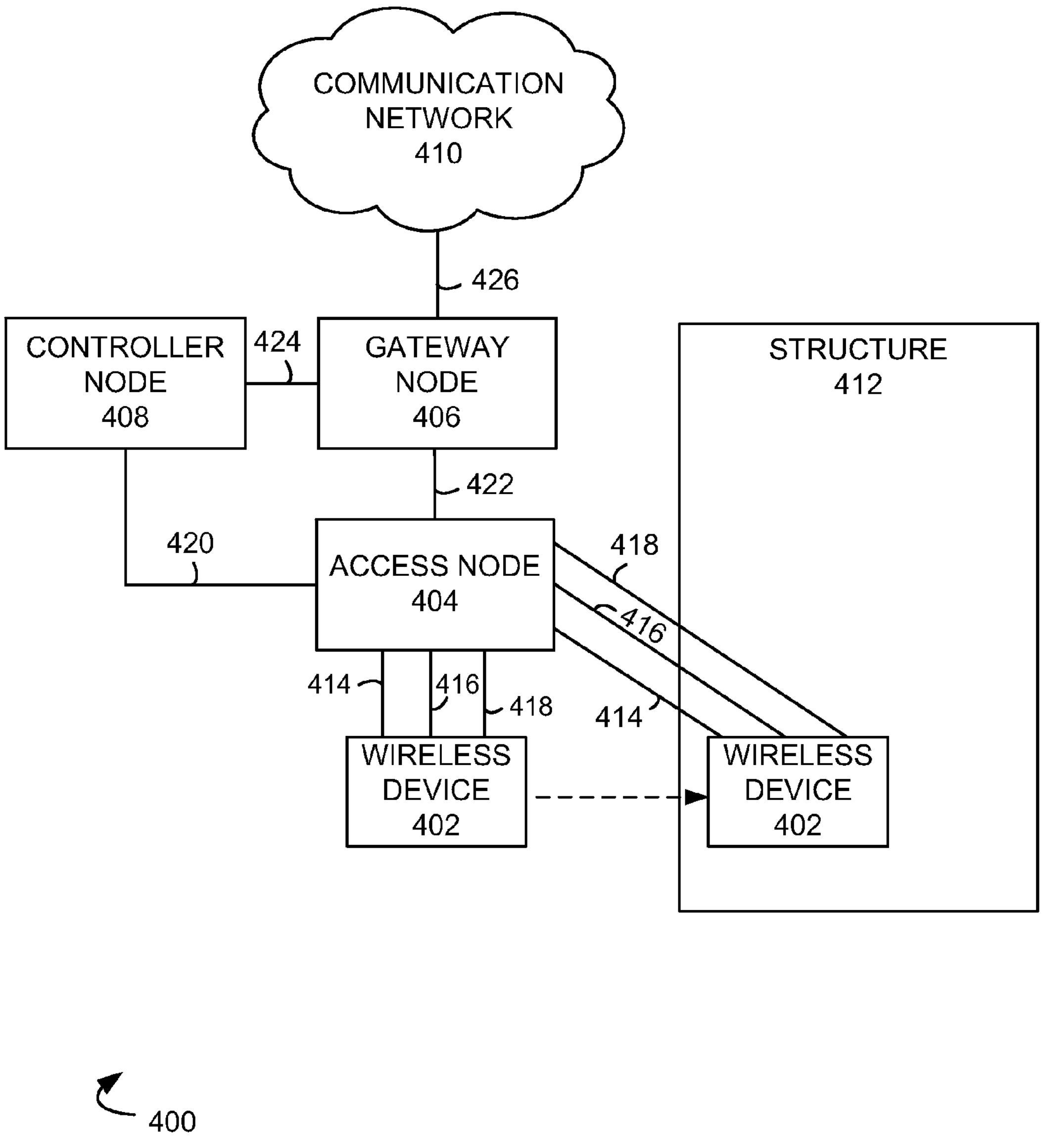

COMMUNICATION
NETWORK
410
426
CONTROLLER
NODE
408
424
GATEWAY
NODE
406
STRUCTURE
412
422
420
ACCESS NODE
404
418
416
414
416
418
414
WIRELESS
DEVICE
402
WIRELESS
DEVICE
402
400

FIG. 4

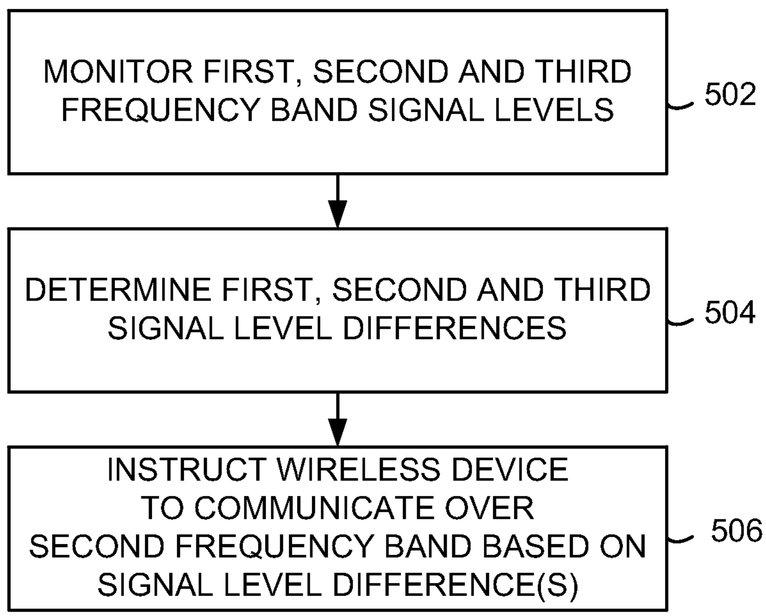

MONITOR FIRST, SECOND AND THIRD FREQUENCY BAND SIGNAL LEVELS
502
DETERMINE FIRST, SECOND AND THIRD SIGNAL LEVEL DIFFERENCES
504
INSTRUCT WIRELESS DEVICE TO COMMUNICATE OVER SECOND FREQUENCY BAND BASED ON SIGNAL LEVEL DIFFERENCE(S)
506

FIG. 5

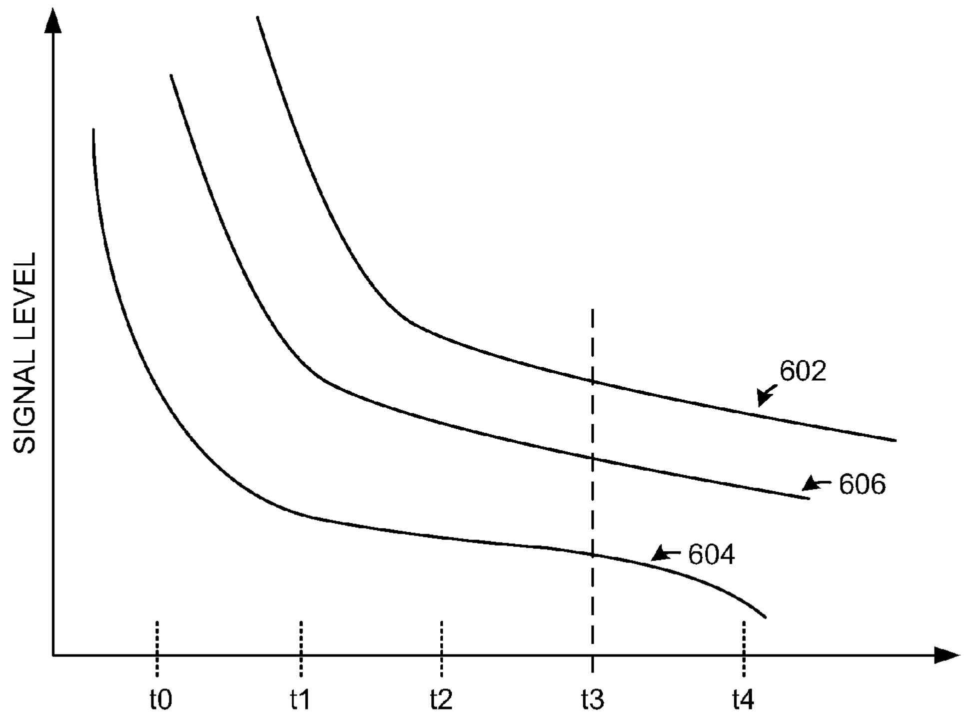
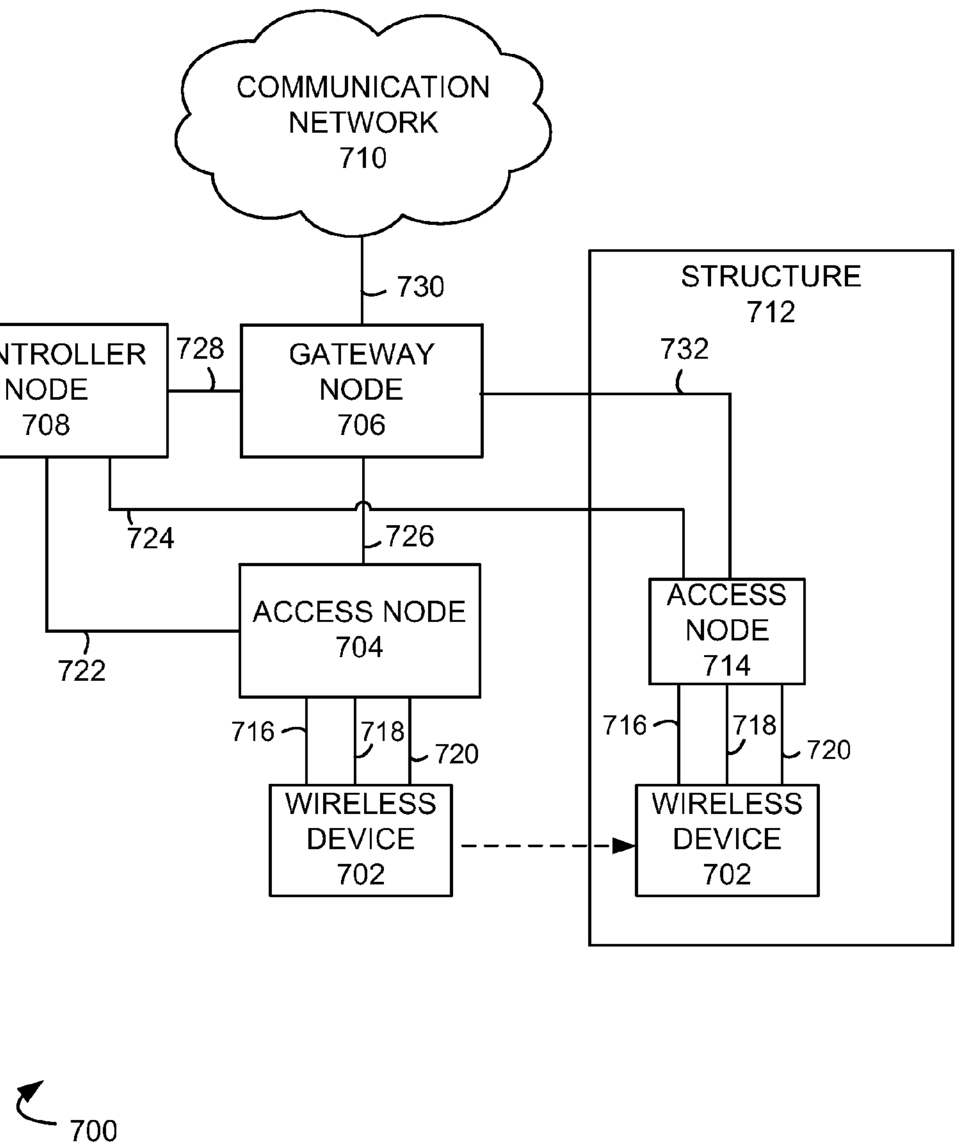


FIG. 6A

	t0	t1	t2	t3	t4
602	-10%	-10%	-10%	-11%	-12%
606	-9%	-9%	-9%	-10%	-10%
604	-11%	-11%	-11%	-15%	-20%

FIG. 6B


COMMUNICATION
NETWORK
710
730
STRUCTURE
712
CONTROLLER
NODE
708
728
GATEWAY
NODE
706
732
724
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ACCESS NODE
704
ACCESS
NODE
714
722
716
718
720
716
718
720
WIRELESS
DEVICE
702
WIRELESS
DEVICE
702
700

FIG. 7

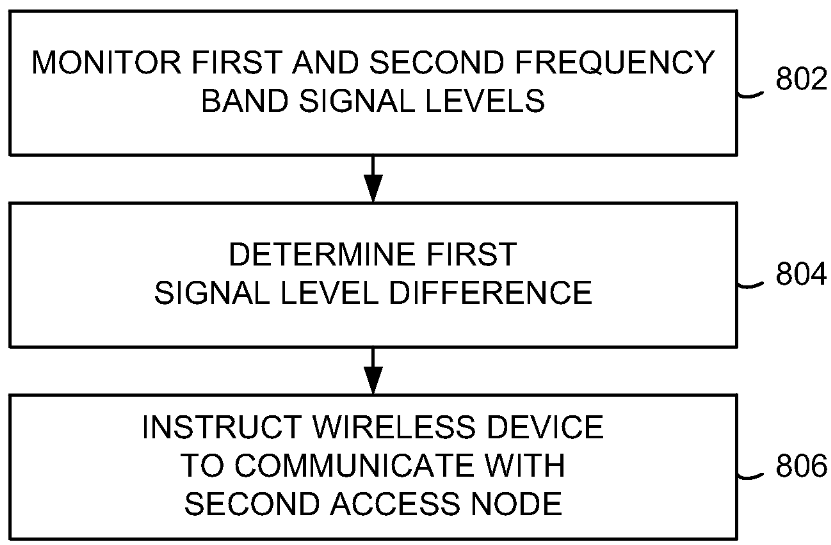
MONITOR FIRST AND SECOND FREQUENCY BAND SIGNAL LEVELS
802
DETERMINE FIRST SIGNAL LEVEL DIFFERENCE
804
INSTRUCT WIRELESS DEVICE TO COMMUNICATE WITH SECOND ACCESS NODE
806

FIG. 8

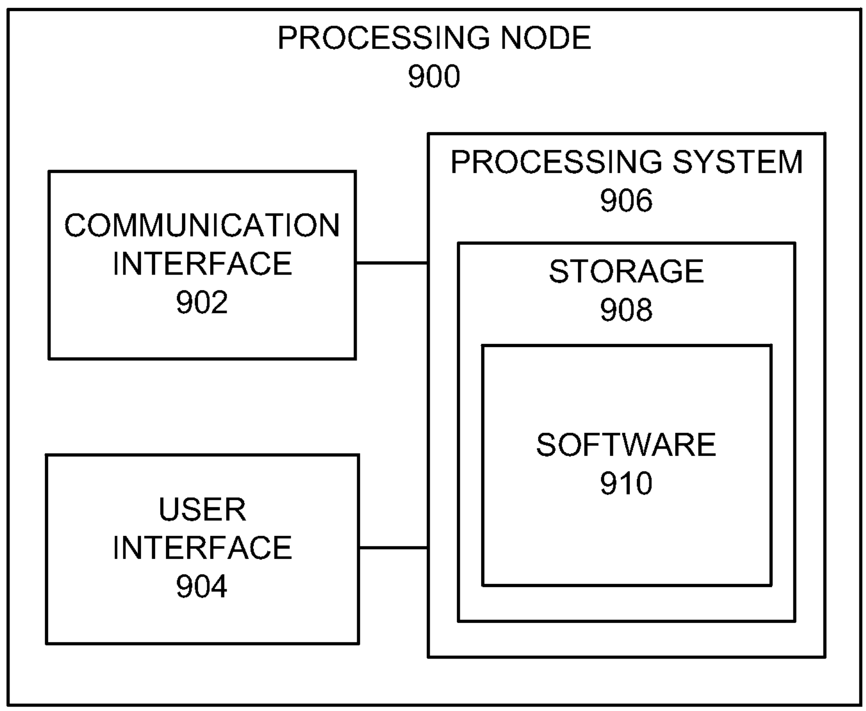
PROCESSING NODE
900
COMMUNICATION
INTERFACE
902
USER
INTERFACE
904
PROCESSING SYSTEM
906
STORAGE
908
SOFTWARE
910

FIG. 9

SYSTEMS AND METHODS OF MANAGING FREQUENCY BAND SELECTION

TECHNICAL BACKGROUND

Multiband wireless communication systems are capable of supporting communication with wireless devices over one or more carriers or frequency bands. Such communication systems can include a plurality of access nodes in relative proximity. Transceivers of a plurality of frequency bands can also be co-located at an access node. Each frequency band may have different characteristics, including coverage, available and total capacity, transmission schemes, and the like. In general, due to physical propagation characteristics, signal levels of higher frequency bands tend to fall off more rapidly than those of lower frequency bands. Higher frequency bands are also more susceptible to path losses due to object interference, such as walls, partitions, and other objects. For example, higher frequency bands tend to penetrate walls and other structures less effectively than lower frequency bands.

Overview

In operation, a first signal level of a first frequency band and a second signal level of a second frequency band which are each received at a wireless device from an access node are monitored. The first frequency band comprises a lower frequency band than the second frequency band. A first signal level difference between the first signal level and the second signal level is determined. When the first signal level difference meets a first signal level difference criteria based on a decrease of the second signal level, the wireless device is instructed to communicate with the access node over the second frequency band. In an embodiment, the wireless device is instructed to communicate over the second frequency band when the second signal level meets a signal level threshold and when the first signal level difference meets a first signal level difference criteria based on a decrease of the second signal level. In an embodiment, the first signal level difference criteria comprises a threshold rate of change over a predetermined period of time.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary communication system to manage frequency band selection for a wireless device.

FIG. **2** illustrates an exemplary method of managing frequency band selection for a wireless device.

FIG. **3**A illustrates exemplary power levels of frequency bands over time.

FIG. **3**B illustrates exemplary signal levels of frequency bands.

FIG. **4** illustrates another exemplary communication system to manage frequency band selection for a wireless device.

FIG. **5** illustrates another exemplary method of managing frequency band selection for a wireless device.

FIG. **6**A illustrates exemplary power levels of frequency bands over time.

FIG. **6**B illustrates exemplary signal levels of frequency bands.

FIG. **7** illustrates another exemplary communication system to manage frequency band selection for a wireless device.

FIG. **8** illustrates another exemplary method of managing frequency band selection for a wireless device.

FIG. **9** illustrates an exemplary processing node.

DETAILED DESCRIPTION

FIG. **1** illustrates an exemplary communication system **100** to manage frequency band selection for a wireless device comprising wireless device **102**, access node **104** and communication network **106**. Examples of wireless device **102** can comprise a cell phone, a smart phone, a computing platform such as a laptop, palmtop, or tablet, a personal digital assistant, or an internet access device, including combinations thereof. Wireless device **102** can communicate with access node **104** over communication link **108** and over communication link **110**. Communication links **108** and **110** can each correspond to a frequency band. In an embodiment, communication link **108** can correspond with a first frequency band, and communication link **110** can correspond with a second frequency band at a lower frequency than the first frequency band.

Access node **104** is a network node capable of providing wireless communications to wireless device **102**, and can be, for example, a base transceiver station, a radio base station, an eNodeB device, or an enhanced eNodeB device. Access node **104** is in communication with communication network **106** over communication link **112**.

Communication network **106** can be a wired and/or wireless communication network, and can comprise processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among various network elements, including combinations thereof, and can include a local area network, a wide area network, and an internetwork (including the Internet). Communication network **106** can be capable of carrying voice information and other data, for example, to support communications by a wireless device such as wireless device **102**. Wireless network protocols may comprise code division multiple access (CDMA) 1xRTT, Global System for Mobile communications (GSM), Universal Mobile Telecommunications System (UMTS), High-Speed Packet Access (HSPA), Evolution Data Optimized (EV-DO), EV-DO rev. A, Worldwide Interoperability for Microwave Access (WiMAX), and Third Generation Partnership Project Long Term Evolution (3GPP LTE). Wired network protocols that may be utilized by communication network **106** comprise Ethernet, Fast Ethernet, Gigabit Ethernet, Local Talk (such as Carrier Sense Multiple Access with Collision Avoidance), Token Ring, Fiber Distributed Data Interface (FDDI), and Asynchronous Transfer Mode (ATM). Communication network **106** may also comprise a wireless network, including base stations, wireless communication nodes, telephony switches, internet routers, network gateways, computer systems, communication links, or some other type of communication equipment, and combinations thereof.

Communication links **108**, **110** and **112** can be wired or wireless communication links. Wired communication links can comprise, for example, twisted pair cable, coaxial cable or fiber optic cable, or combinations thereof. Wireless communication links can comprise a radio frequency, microwave, infrared, or other similar signal, and can use a suitable communication protocol, for example, Global System for Mobile telecommunications (GSM), Code Division Multiple Access (CDMA), Worldwide Interoperability for Microwave Access (WiMAX), or Long Term Evolution (LTE), or combinations thereof. Other wireless protocols can also be used.

Other network elements may be present in communication system **100** to facilitate wireless communication but are omitted for clarity, such as base stations, base station controllers, gateways, mobile switching centers, dispatch application processors, and location registers such as a home location register or visitor location register. Furthermore, other network elements may be present to facilitate communication between access node **104** and communication network **106** which are omitted for clarity, including additional processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among the various network elements.

Frequency bands in multiband wireless communication systems may have different characteristics, including coverage, available and total capacity, transmission schemes, and the like. Different frequency bands typically have different physical propagation characteristics, and higher frequency band signal levels tend to decrease more rapidly than lower frequency band signal levels. Higher frequency bands are also more susceptible than lower frequency bands to path losses due to object interference, such as walls, partitions, and other objects.

Further, higher frequency band signal levels tend to decrease more rapidly than lower frequency band signal levels when a wireless device moves into an area where higher frequency band penetration is impeded. The rapid fall off in higher frequency band signal levels can cause, for example, the degradation of service to or performance of wireless device applications which require a relatively high data rate or data throughput. In addition, wireless communication link load can be increased as a wireless device is assigned a lower modulation and coding scheme (MCS), which tends to decrease data throughput to the wireless device, and may also increase an amount of repetitive data transmitted as part of an error correction mechanism.

In operation, a first signal level of a first frequency band and a second signal level of a second frequency band are monitored, based on signals received at a wireless device from an access node. For example, signal levels received at wireless device **102** corresponding to signals transmitted over communication links **108** and **110** can be monitored. In an embodiment, the first frequency band can be a lower frequency band than the second frequency band. Further, a difference between the first signal level and the second signal level can be determined. In an embodiment, the difference between the first signal level and the second signal level can be determined over a period of time. When the second signal level (of the second frequency band) decreases such that difference of the first signal level and the second signal level meets a first signal level difference criteria, the wireless device can be instructed to communicate with the access node over the second frequency band.

FIG. **2** illustrates an exemplary method of managing frequency band selection for a wireless device. In operation **202**, a first signal level of a first frequency band and a second signal level of a second frequency band are monitored, wherein the first signal level and the second signal level are received at a wireless device from an access node, and wherein the first frequency band comprises a lower frequency band than the second frequency band. For example, with reference to FIG. **3**A, a first signal level **302** and a second signal level **304** can be received at wireless device **102**, and the signal levels can be monitored. Monitoring can be performed at a network element which receives signal level information from wireless device **102** and/or the signal levels can be monitored at wireless device **102**. First signal level **302** can correspond with wireless communication link **108**, and second signal level **304** can correspond with wireless communication link **110**. As illustrated in FIG. **3**A, first signal level **302** can be greater than second signal level **304**. First signal level **302** can correspond with a lower frequency band than second signal level **304**. For example, signal level **302** can correspond with an 800 MHz frequency band, and signal level **304** can correspond with a 2.5 GHz frequency band. Signal levels **302** and **304** are decreasing over time, as illustrated by the decreasing signal levels at times t**0**-t**4**. Such decreasing signal levels can indicate that wireless device **102** is experiencing fading conditions of wireless communication link **108** (and/or wireless communication link **110**), possibly due to wireless device **102** moving away from access node **104**, degrading radio frequency conditions, and the like.

Returning to FIG. **2**, a first signal level difference between the first signal level and the second signal level is determined (operation **204**). In an embodiment, the signal level difference can be determined at a point in time. For example, FIG. **3**A illustrates points in time t**0**, t**1**, t**2**, t**3** and t**4**. Based on the determined respective signal levels, a signal level difference can be determined. For example, FIG. **3**B illustrates variations over time (i.e., rates of change) for the signal levels **302** and **304** determined at times t**0**, t**1**, t**2**, t**3** and t**4**, respectively. In an embodiment, signal levels **302** and **304** can be monitored for a period of time, for example, for a period of time from point t**0** to point t**4**.

Referring again to FIG. **2**, in operation **206**, the wireless device is instructed to communicate with the access node over the second frequency band when the first signal level difference meets a first signal level difference criteria based on a decrease of the second signal level. For example, based on a decrease in signal level **304**, wireless device **102** can be instructed to communicate with access node **104** over wireless communication link **110**. Based on the signal levels determined at t**0**-t**4** (FIGS. **3**A and **3**B) it can be determined (for example, at point t**3**) that the signal level difference meets a threshold signal level difference. The signal level difference can also, for example, meet a threshold signal level rate of change as compared with previous time points. For example, the rate of change of the signal level difference from points t**3**-t**4** can be greater than the rate of change of the signal level difference from points t**0**-t**3**. Further, the rate of change from points t**3**-t**4** can meet a threshold rate of change.

When wireless device **102** moves away from access node **104**, a consistent gradual decrease in signal levels **302** and **304** can be expected. Higher frequency band signal levels tend to decrease more rapidly than lower frequency band signal levels when a wireless device moves into an area where higher frequency band penetration is impeded. For example, the signal level difference evident at point t**3** (or the rate of change evident from points t**3**-t**4**) can indicate, for example, that wireless device **102** has entered a building, passed behind a structure relative to access node **104**, or otherwise entered an area where higher frequency bands are more susceptible than lower frequency bands to signal level loss.

In an embodiment, when the signal level difference meets the signal level difference criteria (for example, at point t**3**, or from points t**3**-t**4**), the wireless device is instructed to communicate with the access node over the second frequency. For example, when the signal level difference meets the signal level difference criteria, it can be determined that wireless device **102** has entered a structure at point t**3**. It can be anticipated that wireless device users who are less mobile (i.e., more stationary) than other wireless device users may use wireless device applications with greater data rate or throughput requirements than wireless devices users who are more mobile. For example, relatively stationary wireless device users may tend to use more streaming multimedia services or other high bandwidth applications than relatively mobile users. To improve a data rate or throughput received by a relatively stationary wireless device, the wireless device can be instructed to communicate with the access node over the second frequency band when the first signal level difference meets a first signal level difference criteria based on a decrease of the second signal level. In an embodiment, the second signal level of the second frequency band is also compared to a signal level threshold, and the wireless device is instructed to communicate over the second frequency band when the second signal level meets a signal level threshold and when the first signal level difference meets a first signal level difference criteria based on a decrease of the second signal level. The signal level threshold can comprise a minimum data rate, a maximum permitted data delay, a minimum throughput, a maximum error rate, a maximum data loss rate, and the like.

FIG. 4 illustrates another exemplary communication system **400** to manage frequency band selection for a wireless device comprising wireless device **402**, access node **404**, gateway node **406**, controller node **408** and communication network **410**. Examples of wireless device **402** can comprise a cell phone, a smart phone, a computing platform such as a laptop, palmtop, or tablet, a personal digital assistant, or an internet access device, including combinations thereof. Wireless device **402** can communicate with access node **404** over communication links **414**, **416** and **418**. Communication links **414**, **416** and **418** can each correspond to a frequency band. In an embodiment, communication link **414** can correspond with a first frequency band, communication link **416** can correspond with a second frequency band at a lower frequency than the first frequency band, and communication link **418** can correspond with a third frequency band lower than the first frequency band and higher than the second frequency band.

Access node **404** is a network node capable of providing wireless communications to wireless device **402**, and can be, for example, a base transceiver station, a radio base station, an eNodeB device, or an enhanced eNodeB device. Access node **404** is in communication with gateway node **406** over communication link **422** and with controller node **408** over communication link **420**.

Gateway node **406** can comprise a processor and associated circuitry to execute or direct the execution of computer-readable instructions, and can be configured to manage frequency band selection for wireless device **402**. Gateway node **406** can retrieve and execute software from storage, which can include a disk drive, flash drive, memory circuitry, or some other memory device, and which can be local or remotely accessible. The software comprises computer programs, firmware, or some other form of machine-readable instructions, and may include an operating system, utilities, drivers, network interfaces, applications, or some other type of software, including combinations thereof. Gateway node **406** can receive instructions and other input at a user interface. Examples of gateway node **406** can include a standalone computing device, a computer system, or a network component, such as an access service network gateway (ASN-GW), a packet data network gateway (P-GW), a serving gateway (S-GW), a mobile switching controller (MSC), a packet data serving node (PDSN), call processing equipment, a home agent, a radio node controller (RNC), a subscriber profile system (SPS), authentication, authorization, and accounting (AAA) equipment, and network gateways, including combinations thereof. Gateway node **406** is in communication with controller node **408** over communication link **424** and with communication network **410** over communication link **426**.

Controller node **408** can comprise can comprise a processor and associated circuitry to execute or direct the execution of computer-readable instructions, and can be configured to manage frequency band selection for wireless device **402**. Controller node **408** can control the setup and maintenance of a communication session over communication network **410** by wireless device **402**. Controller node **408** can comprise a mobile switching center (MSC), a dispatch call controller (DCC), a mobility management entity (MME), or other similar network node. Controller node **408** can retrieve and execute software from storage, which can include a disk drive, flash drive, memory circuitry, or some other memory device, and which can be local or remotely accessible. The software comprises computer programs, firmware, or some other form of machine-readable instructions, and may include an operating system, utilities, drivers, network interfaces, applications, or some other type of software, including combinations thereof. Controller node **408** can receive instructions and other input at a user interface.

Communication network **410** can be a wired and/or wireless communication network, and can comprise processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among various network elements, including combinations thereof, and can include a local area network, a wide area network, and an internetwork (including the Internet). Communication network **410** can be capable of carrying voice information and other data, for example, to support communications by a wireless device such as wireless device **402**. Wireless network protocols may comprise code division multiple access (CDMA) 1xRTT, Global System for Mobile communications (GSM), Universal Mobile Telecommunications System (UMTS), High-Speed Packet Access (HSPA), Evolution Data Optimized (EV-DO), EV-DO rev. A, Worldwide Interoperability for Microwave Access (WiMAX), and Third Generation Partnership Project Long Term Evolution (3GPP LTE). Wired network protocols that may be utilized by communication network **410** comprise Ethernet, Fast Ethernet, Gigabit Ethernet, Local Talk (such as Carrier Sense Multiple Access with Collision Avoidance), Token Ring, Fiber Distributed Data Interface (FDDI), and Asynchronous Transfer Mode (ATM). Communication network **410** may also comprise a wireless network, including base stations, wireless communication nodes, telephony switches, internet routers, network gateways, computer systems, communication links, or some other type of communication equipment, and combinations thereof.

Communication links **414**, **416**, **418**, **420**, **422**, **424** and **426** can be wired or wireless communication links. Wired communication links can comprise, for example, twisted pair cable, coaxial cable or fiber optic cable, or combinations thereof. Wireless communication links can comprise a radio frequency, microwave, infrared, or other similar signal, and can use a suitable communication protocol, for example, Global System for Mobile telecommunications (GSM), Code Division Multiple Access (CDMA), Worldwide Interoperability for Microwave Access (WiMAX), or Long Term Evolution (LTE), or combinations thereof. Other wireless protocols can also be used.

Other network elements may be present in communication system **400** to facilitate wireless communication but are omitted for clarity, such as base stations, base station controllers, gateways, mobile switching centers, dispatch application processors, and location registers such as a home location register or visitor location register. Furthermore, other network elements may be present to facilitate communication between access node **404**, gateway node **406**, controller node **408**, and communication network **410** which are omitted for clarity, including additional processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among the various network elements.

Frequency bands **414**, **416** and **418** may have different physical propagation characteristics. Higher frequency bands may also be more susceptible than lower frequency bands to path losses due to object interference, such as walls, partitions, and other objects. For example, when wireless device **402** enters (or passes behind) structure **412**, which can be an area where higher frequency band penetration is impeded, signal levels of higher frequency bands can be determined to decrease more rapidly than signal levels of lower frequency bands. The relatively rapid fall off in higher frequency band signal levels can cause, for example, the degradation of service to or performance of wireless device applications which require a relatively high data rate or data throughput. In addition, wireless communication link load can be increased as a wireless device is assigned a lower modulation and coding scheme (MCS), which tends to decrease data throughput to the wireless device, and may also increase an amount of repetitive data transmitted as part of an error correction mechanism.

FIG. **5** illustrates another exemplary method of managing frequency band selection for a wireless device. In operation **502**, a first signal level of a first frequency band, a second signal level of a second frequency band, and a third signal level of a third frequency band are monitored, wherein the signal levels are received at a wireless device from an access node. The first frequency band can comprise a lower frequency band than the second frequency band, and the third frequency band can comprise a lower frequency band than the second frequency band and a higher frequency band than the second frequency bands. For example, with reference to FIG. **6**A, a first signal level **602**, a second signal level **604**, and a third signal level **606** can be received at wireless device **402** and monitored. First signal level **602** can correspond with wireless communication link **414**, second signal level **604** can correspond with wireless communication link **416**, and third signal level **606** can correspond with wireless communication link **418**. As illustrated in FIG. **6**A, first signal level **602** can be greater than second signal level **604** and third signal level **606**, and second signal level **604** can be lower than third signal level **606**. First signal level **602** can correspond with a lower frequency band than second signal level **604** and third signal level **606**, and third signal level **606** can correspond with a lower frequency level than second signal level **604**. For example, signal level **602** can correspond with an 800 MHz frequency band, signal level **604** can correspond with a 2.5 GHz frequency band, and third signal level **606** can correspond with a 1.9 GHz frequency band. Signal levels **602**, **604** and **606** are decreasing over time, as illustrated by the decreasing signal levels at times t**0**-t**4**. Such decreasing signal levels can indicate that wireless device **402** is experiencing fading conditions of wireless communication links **414**, **416** and/or **418**, possibly due to wireless device **402** moving away from access node **404**, degrading radio frequency conditions, and the like.

Returning to FIG. **5**, a signal level difference among signal levels the first, second and third frequency bands are determined (operation **504**). For example, a first signal level difference between the first signal level and the second signal level can be determined. In addition, a second signal level difference between the second signal level and the third signal can also be determined. Further, a third signal level between the first signal level and the third signal level can also be determined. In an embodiment, the signal level differences can be determined at a point in time. For example, referring to FIG. **6**A, based on the determined respective signal levels, the first, second and third signal level differences can be determined at points in time t**0**, t**1**, t**2**, t**3** and t**4**. FIG. **6**B illustrates variations over time (i.e., rates of change) for the signal levels **602**, **604** and **606** determined at times t**0**, t**1**, t**2**, t**3** and t**4**, respectively. In an embodiment, signal levels **602**, **604** and **606** can be monitored for a period of time, for example, for a period of time from point t**0** to point t**4**.

Referring again to FIG. **5**, in operation **506**, the wireless device is instructed to communicate with the access node over the second frequency band when the first signal level difference meets a first signal level difference criteria based on a decrease of the second signal level. For example, based on a decrease in signal level **604** (FIG. **6**A), wireless device **402** can be instructed to communicate with access node **404** over wireless communication link **416**. Based on the signal levels determined at t**0**-t**4** (FIGS. **6**A and **6**B) it can be determined (for example, at point t**3**) that the signal level difference meets a threshold signal level difference. For example, the first signal level difference at point t**3** can be 4%, as compared to 1% at points t**0**-t**2**. The first signal level difference can also, for example, meet a threshold signal level rate of change as compared with previous time points. For example, the rate of change of the first signal level difference from points t**3**-t**4** can be greater than the rate of change of the first signal level difference from points t**0**-t**3**. Further, the rate of change from points t**3**-t**4** can meet a threshold rate of change.

In an embodiment, wireless device **402** can be instructed to communicate with access node **404** over the second frequency band when the first signal level difference meets a first signal level difference criteria and when the second signal level difference meets a second signal level difference criteria, each based on a decrease of the second signal level. For example, differences of the first signal level and the second signal level, and of the third signal level and the second signal level, can be monitored to determine when both signal level differences meet thresholds (which can be different thresholds). As another example, a rate of change of the difference of the first signal level and the second signal level, and a second rate of change of the difference of the second signal level and the third signal level, can be monitored to determine when both signal level differences meet threshold rates of change (which can be different threshold rates of change).

In an embodiment, wireless device **402** can be instructed to communicate with access node **404** over the second frequency band when the first signal level difference meets a first signal level difference criteria and when the third signal level difference meets a third signal level difference criteria, based on a decrease of the second signal level. For example, differences of the first signal level and the second signal level, and of the first signal level and the third signal level, can be monitored to determine when both signal level differences meet thresholds. In an embodiment, the third signal level difference can be compared with the first signal level difference to more accurately determine the first signal level difference meets a signal level difference threshold. As another example, a rate of change of the difference of the first signal level and the second signal level, and a second rate of change of the difference of the first signal level and the third signal level, can be monitored to determine when the rate of change of the first signal level meets a threshold rate of change.

FIG. **7** illustrates another exemplary communication system **700** to manage frequency band selection for a wireless device comprising wireless device **702**, access node **704**, gateway node **706**, controller node **708**, communication network **410**, and access node **714**. Examples of wireless device **702** can comprise a cell phone, a smart phone, a computing platform such as a laptop, palmtop, or tablet, a personal digital assistant, or an internet access device, including combinations thereof. Wireless device **702** can communicate with access node **704** over communication links **716**, **718** and **720**. Communication links **716**, **718** and **720** can each correspond to a frequency band. In an embodiment, communication link **716** can correspond with a first frequency band, communication link **718** can correspond with a second frequency band at a lower frequency than the first frequency band, and communication link **720** can correspond with a third frequency band lower than the first frequency band and higher than the second frequency band.

Access node **704** is a network node capable of providing wireless communications to wireless device **702**, and can be, for example, a base transceiver station, a radio base station, an eNodeB device, or an enhanced eNodeB device. Access node **704** is in communication with gateway node **706** over communication link **726** and with controller node **708** over communication link **722**.

Gateway node **706** can comprise a processor and associated circuitry to execute or direct the execution of computer-readable instructions, and can be configured to manage frequency band selection for wireless device **702**. Gateway node **706** can retrieve and execute software from storage, which can include a disk drive, flash drive, memory circuitry, or some other memory device, and which can be local or remotely accessible. The software comprises computer programs, firmware, or some other form of machine-readable instructions, and may include an operating system, utilities, drivers, network interfaces, applications, or some other type of software, including combinations thereof. Gateway node **706** can receive instructions and other input at a user interface. Examples of gateway node **706** can include a standalone computing device, a computer system, or a network component, such as an access service network gateway (ASN-GW), a packet data network gateway (P-GW), a serving gateway (S-GW), a mobile switching controller (MSC), a packet data serving node (PDSN), call processing equipment, a home agent, a radio node controller (RNC), a subscriber profile system (SPS), authentication, authorization, and accounting (AAA) equipment, and network gateways, including combinations thereof. Gateway node **706** is in communication with controller node **708** over communication link **728** and with communication network **710** over communication link **730**.

Controller node **708** can comprise can comprise a processor and associated circuitry to execute or direct the execution of computer-readable instructions, and can be configured to manage frequency band selection for wireless device **702**. Controller node **408** can control the setup and maintenance of a communication session over communication network **710** by wireless device **702**. Controller node **708** can comprise a mobile switching center (MSC), a dispatch call controller (DCC), a mobility management entity (MME), or other similar network node. Controller node **708** can retrieve and execute software from storage, which can include a disk drive, flash drive, memory circuitry, or some other memory device, and which can be local or remotely accessible. The software comprises computer programs, firmware, or some other form of machine-readable instructions, and may include an operating system, utilities, drivers, network interfaces, applications, or some other type of software, including combinations thereof. Controller node **708** can receive instructions and other input at a user interface.

Communication network **710** can be a wired and/or wireless communication network, and can comprise processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among various network elements, including combinations thereof, and can include a local area network, a wide area network, and an internetwork (including the Internet). Communication network **710** can be capable of carrying voice information and other data, for example, to support communications by a wireless device such as wireless device **702**. Wireless network protocols may comprise code division multiple access (CDMA) 1xRTT, Global System for Mobile communications (GSM), Universal Mobile Telecommunications System (UMTS), High-Speed Packet Access (HSPA), Evolution Data Optimized (EV-DO), EV-DO rev. A, Worldwide Interoperability for Microwave Access (WiMAX), and Third Generation Partnership Project Long Term Evolution (3GPP LTE). Wired network protocols that may be utilized by communication network **710** comprise Ethernet, Fast Ethernet, Gigabit Ethernet, Local Talk (such as Carrier Sense Multiple Access with Collision Avoidance), Token Ring, Fiber Distributed Data Interface (FDDI), and Asynchronous Transfer Mode (ATM). Communication network **710** may also comprise a wireless network, including base stations, wireless communication nodes, telephony switches, internet routers, network gateways, computer systems, communication links, or some other type of communication equipment, and combinations thereof.

Access node **714** is a network node capable of providing wireless communications to wireless device **702** over communication links **716**, **718** and **720**, corresponding to the first frequency band, the second frequency band, and the third frequency band, respectively. In an embodiment, the first, second and third frequency bands can each use a cellular radio access technology, examples of which include LTE, WiMAX, CDMA, and the like. Access node **714** is substantially disposed within structure **712**, and can comprise a coverage area which is itself within a coverage area of access node **704**. Examples of access node **714** can include a base transceiver station, a radio base station, an eNodeB device, an enhanced eNodeB device, or other similar access node, including a so-called femtocell device, picocell device, and the like, which can be used to enhance or supplement network coverage of communication system **700**. Access node **714** is in communication with controller node **708** over communication link **722** and with gateway node **706** over communication link **730**.

Communication links **716**, **718**, **720**, **722**, **724**, **726**, **728**, **730** and **732** can be wired or wireless communication links. Wired communication links can comprise, for example, twisted pair cable, coaxial cable or fiber optic cable, or combinations thereof. Wireless communication links can comprise a radio frequency, microwave, infrared, or other similar signal, and can use a suitable communication protocol, for example, Global System for Mobile telecommunications (GSM), Code Division Multiple Access (CDMA), Worldwide Interoperability for Microwave Access (WiMAX), or Long Term Evolution (LTE), or combinations thereof. Other wireless protocols can also be used.

Other network elements may be present in communication system **700** to facilitate wireless communication but are omitted for clarity, such as base stations, base station controllers, gateways, mobile switching centers, dispatch application processors, and location registers such as a home location register or visitor location register. Furthermore, other network elements may be present to facilitate communication between access node **704**, gateway node **706**, controller node **708**, access node **714**, and communication network **710** which are omitted for clarity, including additional processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among the various network elements.

Frequency bands **716**, **718** and **720** may have different physical propagation characteristics. Higher frequency bands may also be more susceptible than lower frequency bands to path losses due to object interference, such as walls, partitions, and other objects. For example, when wireless device **702** enters structure **712**, which can be an area where higher frequency band penetration is impeded, signal levels of higher frequency bands can be determined to decrease more rapidly than signal levels of lower frequency bands. The rapid fall off in higher frequency band signal levels can cause, for example, the degradation of service to or performance of wireless device applications which require a relatively high data rate or data throughput. In addition, wireless communication link load can be increased as a wireless device is assigned a lower modulation and coding scheme (MCS), which tends to decrease data throughput to the wireless device, and may also increase an amount of repetitive data transmitted as part of an error correction mechanism.

FIG. **8** illustrates another exemplary method of managing frequency band selection for a wireless device. In operation **802**, a first signal level of a first frequency band, a second signal level of a second frequency band, wherein the signal levels are received at a wireless device from an access node. The first frequency band can comprise a lower frequency band than the second frequency band. In an embodiment, a third signal level of a third frequency band can also be monitored, and the third frequency band can comprise a lower frequency band than the second frequency band and a higher frequency band than the second frequency bands. For example, the first signal level can correspond with an 800 MHz frequency band, and the second signal level can correspond with a 2.5 GHz frequency band. In an embodiment, the third signal level can correspond with a 1.9 GHz frequency band.

In operation **804** a signal level difference of the first and second frequency bands are determined. For example, a first signal level difference between the first signal level and the second signal level can be determined. In an embodiment, a second signal level difference between the second signal level and the third signal can also be determined. Further, in an embodiment, a third signal level between the first signal level and the third signal level can also be determined. The signal level differences can be determined at a point in time. For example, referring to FIG. **6**A, based on the determined respective signal levels, the first, second and third signal level differences can be determined at points in time t**0**, t**1**, t**2**, t**3** and t**4**. FIG. **6**B illustrates signal levels determined at times t**0**, t**1**, t**2**, t**3** and t**4**, for signal levels **602**, **604** and **606**, respectively. In an embodiment, signal levels **602**, **604** and **606** can be monitored for a period of time, for example, for a period of time from point t**0** to point t**4**.

Referring again to FIG. **8**, in operation **806**, the wireless device is instructed to communicate with a second access node over the second frequency band when the first signal level difference meets a first signal level difference criteria based on a decrease of the second signal level. For example, based on a decrease in signal level **604** (FIG. **6**A), wireless device **702** can be instructed to communicate with access node **7144** over wireless communication link **718**. Based on the signal levels determined at t**0**-t**4** (FIGS. **6**A and **6**B) it can be determined (for example, at point t**3**) that the signal level difference meets a threshold signal level difference. For example, the first signal level difference at point t**3** can be 4%, as compared to 1% at points t**0**-t**2**. The first signal level difference can also, for example, meet a threshold signal level rate of change as compared with previous time points. For example, the rate of change of the first signal level difference from points t**3**-t**4** can be greater than the rate of change of the first signal level difference from points t**0**-t**3**. Further, the rate of change from points t**3**-t**4** can meet a threshold rate of change.

In an embodiment, wireless device **702** can be instructed to communicate with access node **714** over the second frequency band when the first signal level difference meets a first signal level difference criteria and when the second signal level difference meets a second signal level difference criteria, each based on a decrease of the second signal level. For example, differences of the first signal level and the second signal level, and of the third signal level and the second signal level, can be monitored to determine when both signal level differences meet thresholds (which can be different thresholds). As another example, a rate of change of the difference of the first signal level and the second signal level, and a second rate of change of the difference of the second signal level and the third signal level, can be monitored to determine when both signal level differences meet threshold rates of change (which can be different threshold rates of change).

In an embodiment, wireless device **702** can be instructed to communicate with access node **714** over the second frequency band when the first signal level difference meets a first signal level difference criteria and when the third signal level difference meets a third signal level difference criteria, based on a decrease of the second signal level. For example, differences of the first signal level and the second signal level, and of the first signal level and the third signal level, can be monitored to determine when both signal level differences meet thresholds. In an embodiment, the third signal level difference can be compared with the first signal level difference to more accurately determine the first signal level difference meets a signal level difference threshold. As another example, a rate of change of the difference of the first signal level and the second signal level, and a second rate of change of the difference of the first signal level and the third signal level, can be monitored to determine when the rate of change of the first signal level meets a threshold rate of change.

FIG. **9** illustrates an exemplary processing node **900** in a communication system. Processing node **900** comprises communication interface **902**, user interface **904**, and processing system **906** in communication with communication interface **902** and user interface **904**. Processing node **900** can be configured to manage frequency band selection for a wireless device. Processing system **906** includes storage **908**, which can comprise a disk drive, flash drive, memory circuitry, or other memory device. Storage **908** can store software **910** which is used in the operation of the processing node **900**. Storage **908** may include a disk drive, flash drive, data storage circuitry, or some other memory apparatus. Software **910** may include computer programs, firmware, or some other form of machine-readable instructions, including an operating system, utilities, drivers, network interfaces, applications, or some other type of software. Processing system **906** may include a microprocessor and other circuitry to retrieve and execute software **910** from storage **908**. Processing node **900** may further include other components such as a power management unit, a control interface unit, etc., which are omitted for clarity. Communication interface **902** permits processing node **900** to communicate with other network elements. User interface **904** permits the configuration and control of the operation of processing node **900**.

Examples of processing node **900** include gateway node **406**, controller node **408**, gateway node **706**, and controller node **708**. Processing node **900** can also be an adjunct or component of a network element, such as an element of access node **104**, access node **404**, access node **704** and access node **714**. Processing node **900** can also be another network element in a communication system. Further, the functionality of processing node **900** can be distributed over two or more network elements.

The exemplary systems and methods described herein can be performed under the control of a processing system executing computer-readable codes embodied on a computer-readable recording medium or communication signals transmitted through a transitory medium. The computer-readable recording medium is any data storage device that can store data readable by a processing system, and includes both volatile and nonvolatile media, removable and non-removable media, and contemplates media readable by a database, a computer, and various other network devices.

Examples of the computer-readable recording medium include, but are not limited to, read-only memory (ROM), random-access memory (RAM), erasable electrically programmable ROM (EEPROM), flash memory or other memory technology, holographic media or other optical disc storage, magnetic storage including magnetic tape and magnetic disk, and solid state storage devices. The computer-readable recording medium can also be distributed over network-coupled computer systems so that the computer-readable code is stored and executed in a distributed fashion. The communication signals transmitted through a transitory medium may include, for example, modulated signals transmitted through wired or wireless transmission paths.

The above description and associated figures teach the best mode of the invention. The following claims specify the scope of the invention. Note that some aspects of the best mode may not fall within the scope of the invention as specified by the claims. Those skilled in the art will appreciate that the features described above can be combined in various ways to form multiple variations of the invention, and that various modifications may be made to the configuration and methodology of the exemplary embodiments disclosed herein without departing from the scope of the present teachings. Those skilled in the art also will appreciate that various features disclosed with respect to one exemplary embodiment herein may be used in combination with other exemplary embodiments with appropriate modifications, even if such combinations are not explicitly disclosed herein. As a result, the invention is not limited to the specific embodiments described above, but only by the following claims and their equivalents.

What is claimed is:

1. A method of managing frequency band selection for a wireless device, comprising:

monitoring a first signal level of a first frequency band a second signal level of a second frequency band, and a third signal level of a third frequency band, wherein the first frequency band comprises a lower frequency band than the second and third frequency bands;

determining a first signal level difference between the first and the second signal levels;

determining a second signal level difference between the second and the third signal levels; and

instructing the wireless device to communicate with the access node over the second frequency band when a rate of change of the first signal level difference and a rate of change of the second signal level difference meet a criteria based on a decrease of the second signal level.

2. The method of claim **1**, further comprising;

instructing the wireless device to communicate over the second frequency band when the second signal level meets a signal level threshold and when the first signal level difference meets a first signal level difference criteria based on a decrease of the second signal level; and

instructing the wireless device to communicate over the second frequency band when the second signal level difference meets a second signal level difference threshold based on a decrease of the second signal level.

3. The method of claim **2**, wherein the criteria comprises a threshold rate of change over a predetermined period of time.

4. The method of claim **2**,

wherein the third frequency band comprises a lower frequency band than the second frequency band and a higher frequency band than the first frequency band.

5. The method of claim **4**, further comprising:

determining a third signal level difference between the first signal level and the third signal level.

6. The method of claim **4**, further comprising:

determining a third signal level difference between the first signal level and the third signal level; and

instructing the wireless device to communicate over the second frequency band when a ratio of the first signal level difference to the second signal level difference meets a criteria based on a decrease of the second signal level.

7. The method of claim **4**, further comprising:

determining a third signal level difference between the first signal level and the third signal level; and

instructing the wireless device to communicate over the second frequency band when the first signal level difference is a predetermined percentage greater than the second signal level difference based on a decrease of the second signal level.

8. The method of claim **4**, further comprising:

determining a third signal level difference between the first signal level and the third signal level; and

instructing the wireless device to communicate over the second frequency band when the first signal level difference is a predetermined ratio greater than the second signal level difference based on a decrease of the second signal level.

9. The method of claim **1**, further comprising determining that the wireless device is indoors when the first signal level difference meets a first signal level difference threshold based on a decrease of the second signal level.

10. A system of managing frequency band selection for a wireless device, comprising:

a processing node configured to:

monitor a first signal level of a first frequency band, a second signal level of a second frequency band, and a third signal level of a third frequency band, wherein the first frequency band comprises a lower frequency band than the second and third frequency bands;

determine a first signal level difference between the first and the second signal levels;

determine a second signal level difference between the second and the third signal levels; and

instruct the wireless device to communicate with the access node over the second frequency band when a rate of change of the first signal level difference and a rate of change of the second signal level difference meet a criteria based on a decrease of the second signal level, wherein the criteria comprises a threshold rate of change over a predetermined period of time.

11. The system of claim **10**, wherein the processing node is further configured to:

instruct the wireless device to communicate over the second frequency band when the second signal level difference meets a second signal level difference threshold based on a decrease of the second signal level.

12. The system of claim **11**, wherein the processing node is further configured to:

determine a third signal level difference between the first signal level and the third signal level, wherein the third signal level of the third frequency band comprises a lower frequency band than the second frequency band and a higher frequency band than the first frequency band.

13. The system of claim **11**, wherein the processing node is further configured to:

determine a third signal level difference between the first signal level and the third signal level; and

instruct the wireless device to communicate over the second frequency band when a ratio of the first signal level difference to the second signal level difference meets a criteria based on a decrease of the second signal level.

14. The system of claim **11**, wherein the processing node is further configured to:

determine a third signal level difference between the first signal level and the third signal level; and

instruct the wireless device to communicate over the second frequency band when the first signal level difference is a predetermined percentage greater than the second signal level difference based on a decrease of the second signal level.

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